BI-DIRECTIONAL NITROGEN TRANSFER BETWEEN LEGUME AND NON-LEGUME PLANTS.

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ABSTRACT

Non-N_2-fixing crops intercropped with legumes may benefit through transfer of symbiotically fixed N from the legume crop. The pattern of N transfer by mechanisms non dependent on decomposition of plant tissues was studied in a greenhouse. In addition, a study accessed the effect of intercropped alfalfa (*Medicago sativa* L.) on meadow bromegrass (*Bromus riparius* Rhem.) forage and N yield by a combination of N transfer mechanisms occurring under field conditions. In the first study, shoot portions of one alfalfa or one bromegrass plant (donor) were foliarly fed with ^{15}N labelled ammonium sulphate. No ^{15}N from bromegrass was transferred to alfalfa, whereas ^{15}N from alfalfa plants was transferred mainly to bromegrass plants. Transfer of ^{15}N between plants of the same species was not significant in alfalfa and only detected in the nearest plant of bromegrass. The ^{15}N content of the receptor plants showed that underground movement of ^{15}N between plants occurred within 3 days. In the field study, swards of single bromegrass and alfalfa intercropped with bromegrass were seeded in rows 17.8 cm apart. In the following year individual rows of plants, adjacent to each other, on both sides of the edge between the different swards were harvested separately for dry matter (DM) and N yield. Results of bromegrass were related to distance from the nearest row of alfalfa. Forage yield gradually increased from 427 to 1230 kg ha^{-1} and N yield increased from 53 to 184 kg ha^{-1} as the distance between the bromegrass row and the alfalfa row decreased from 71.1 cm to 17.8 cm. Yield of bromegrass located up to 35.6 cm from alfalfa was significantly increased, indicating transfer of N from alfalfa to bromegrass in agronomically relevant amounts.

INTRODUCTION

Nitrogen (N) is a major limiting nutrient for plant growth throughout the world. Use of N fertilizer to enhance the growth of grass in grass-legume associations has been frequently reported to inhibit N_2 fixation by the legume-*Rhizobium* symbiosis (Gibson and Harper, 1985).

An increased knowledge about interspecific N transfer is promising as an improved basis for management decisions to increase productivity of legume-grass associations and reduce the dependency on N fertilizers. Enhanced N transfer has the potential to improve the productivity of mixed forages, cereal-pulses, and mixed forest productivity without increasing the use of N fertilizers.

Nitrogen transfer has often been defined as the movement of N from a growing legume to a non-legume (usually a *Gramineae* plant) (Brophy *et al.*, 1987). These authors pointed out that N from grasses can also be transferred to associated legumes, but would be unlikely under N limited growth conditions.

Brophy et al.(1987) concluded from ^{15}N field studies that a high proportion of grass N was obtained from the intercropped leguminous plant. These authors found that reed canarygrass (*Phalaris arundinacea* L.) derived up to 68% of its N from associated alfalfa, equivalent to 17% of the N_2 fixed by the alfalfa. The study also indicated that: (a) N transfer occurs over a distance of at least 20 cm; (b) maximum transfer of N occurs at a legume to grass ratio greater than 1:1; and (c) a greater proportion of legume N is derived from symbiotic N_2 fixation rather than from soil N where legumes, such as alfalfa, are grown in mixture with grasses than as sole crops. Other field studies using the labelled ^{15}N isotope dilution technique showed that between 6 and 12% of perennial ryegrass (*Lolium perenne* L.) N content was derived from intercropped white clover (*Trifolium repens* L.) (Haystead and Marriot, 1978; 1979).

The mechanisms of interspecific N transfer are classified as indirect or direct based on, respectively, whether decomposition of plant tissues is or is not involved before the transferred N is absorbed by the receiving plant.

A greenhouse study was carried with the objective of verifying the occurrence and pattern of these direct N transfer mechanisms. In addition, a field study was conducted to estimate the combined effect of direct and indirect mechanisms of N transfer.

MATERIAL AND METHODS

Meadow bromegrass cv. Fleet and alfalfa cv. Beaver were used in both the greenhouse and the field studies. Similarly, both studies were conducted on light textured, sandy loam, soil with limited N supply capacity as evidenced by the yellowish color, characteristic of N deficiency, displayed by bromegrass plants not intercropped with alfalfa.

Direct N transfer study

The greenhouse set up consisted of 25 cm diameter pots, with 8 kg of sandy loam soil, and initial level of NO_3-N of 19 ppm, supplied regularly with N-free nutrient solution. Three plants of bromegrass and three plants of alfalfa, spaced 6 cm between and within rows were grown in pots for 181 days after transplanting. Small shoot portions of one alfalfa or one bromegrass plant (donor) located at the end of a row were foliarly fed with ^{15}N labelled ammonium sulphate during 64 hours. The mean ^{15}N-enrichment achieved in the alfalfa donor plants was about twice as high as that of bromegrass (0.73495 vs. 0.32492 % atom excess).

Treatments consisted of five individual non-^{15}N-labelled (receiving) plants and each randomized complete block consisted of a single pot. Each experiment consisted of a pot with a ^{15}N labelled alfalfa or bromegrass plant, replicated five times. The atom % ^{15}N abundances of alfalfa (0.36761) and bromegrass (0.36915) plants grown in five pots with no ^{15}N label (controls) were used for calculating the atom % ^{15}N

excess in both experiments. The pots were watered at the start of the foliar immersion period and did not receive water until the end of the experiment.

Transfer was considered significant when the mean atom % ^{15}N excess for a treatment was higher than zero by the Fisher's protected LSD at $P \leq 0.05$ or $P \leq 0.10$, respectively for the experiments having alfalfa and bromegrass as donors. A $P \leq 0.10$ level of significance was required for a protected LSD test.

N transfer by a combination of direct and indirect mechanisms

Swards of meadow bromegrass and alfalfa were seeded in rows 17.8 cm apart on an irrigated sandy loam soil near Outlook, SK (Saskatchewan Irrigation Development Center), on May 23, 1990 and then managed as hay crops. Fertilizers were broadcasted at a rate of 20 kg of P ha^{-1} before seeding and 44 kg of P plus 436 kg of K ha^{-1} on July 12, 1991. The experiment was set up in a randomized complete block design, replicated 4 times, with plot size of 3 m by 6.25 m. The plots were established as single bromegrass and alfalfa intercropped with bromegrass in alternate rows. On August 12, 1991, forage was harvested for dry matter and N yield from 1 m row of plants. Each replicate was made of a set of 8 adjacent individual rows of plants: four rows of plants on each side of the edge between single bromegrass and intercropped bromegrass+alfalfa plots.

All data were subjected to ANOVA. Data transformations were done by $y = \log_e x$, as determined by the F max procedure at $P \leq 0.05$ (David, 1952) to fulfil the assumption of homogeneity of variances required for a valid ANOVA (Steel and Torrie, 1980). Fisher's protected LSD procedure ($P \leq 0.05$) was used to compare the transformed treatment means.

RESULTS

Direct N transfer: transfer of ^{15}N in 64 hours

Transfer of ^{15}N derived from the legume had a distinct pattern (Figure 1a) from that derived from the non-legume species (Figure 1b). ^{15}N transfer from alfalfa was detected on the two bromegrass plants situated at a distance of 6 and 8.5 cm (Figure 1a), however, no significant transfer of ^{15}N to any of the alfalfa plants sharing the same soil environment was detected. Transfer of ^{15}N from bromegrass was only detected on the nearest plant of the same species (Figure 1b). No transfer to the legume plant situated at the same distance (6 cm) was detected.

N transfer by combination of direct and indirect mechanisms: Effect of alfalfa on bromegrass forage and N yield

Results of bromegrass were related to distance from the nearest row of alfalfa (Figure 2). Bromegrass forage yield gradually increased from 427 to 1230 kg ha^{-1} (Figure 2a) and N yield increased from 53 to 184 kg ha^{-1} (Figure 2b) as the distance between the bromegrass row and the alfalfa row decreased from 71.1 cm to 17.8 cm. Significantly higher bromegrass DM and N yield were detected on plants located up

Figure 1. The ^{15}N transfer from alfalfa (a) or bromegrass (b) during 64 hours as measured by atom % ^{15}N excess in non-labelled alfalfa and bromegrass plants.

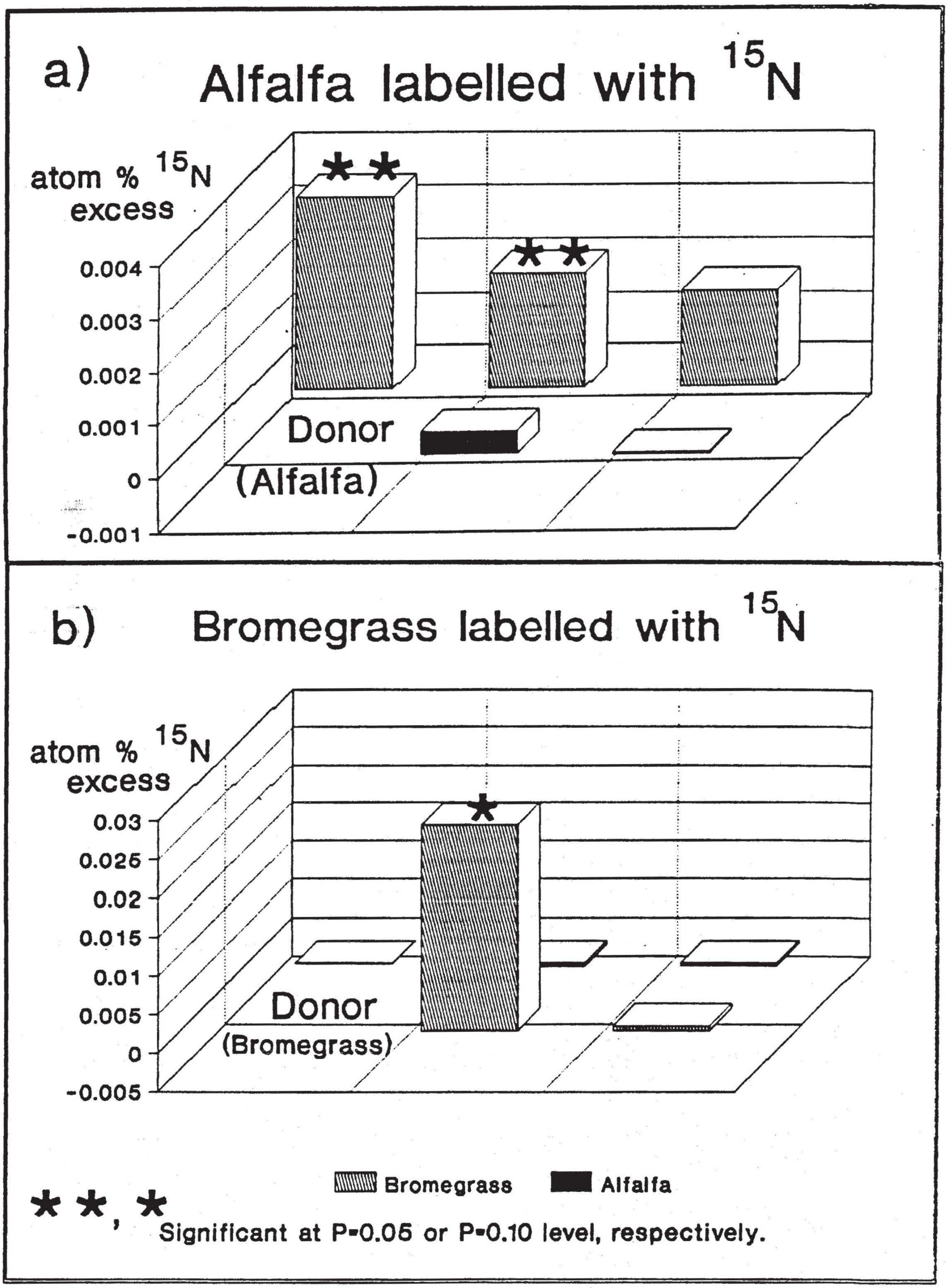
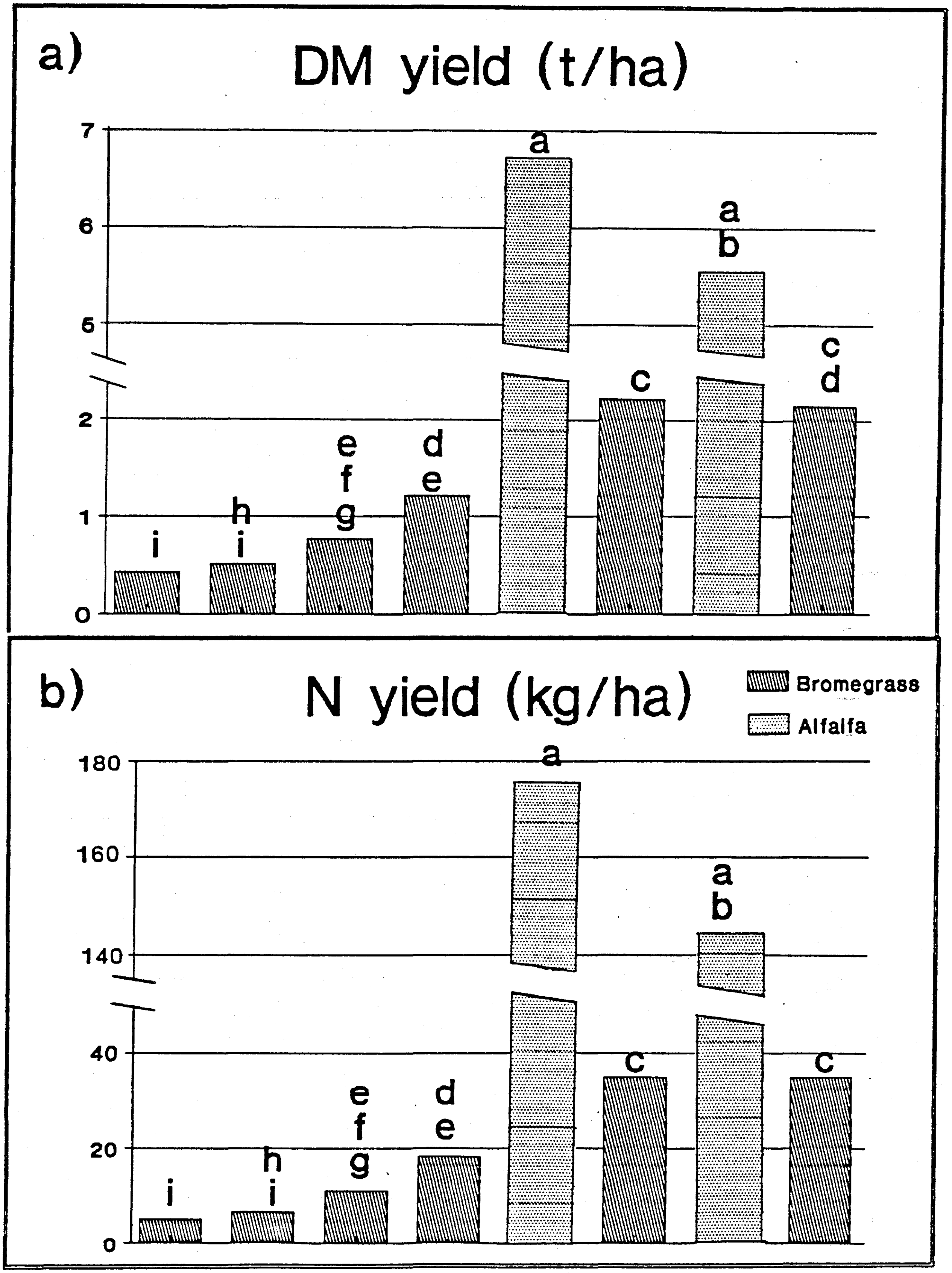


Figure 2. Forage DM and N of alfalfa and bromegrass grown at a distance of 17.8, 35.6, 53.4 or 71.2 cm from alfalfa plants.



Means followed by a common letter do not differ ($P \leq 0.05$) by Fisher's protected LSD test.

to 35.6 cm apart from alfalfa plants than on bromegrass located at a further distance from alfalfa plants. However, the DM and N yield of bromegrass plants located between alfalfa plants was much higher than that of bromegrass plants having alfalfa as neighbours in only one side.

DISCUSSION

Direct N transfer: transfer of ^{15}N in 64 hours

Uptake of ^{15}N by foliar feeding, incorporation of ^{15}N in plant tissues, decomposition of ^{15}N labelled tissues and uptake of transferred ^{15}N by a receptor plant are not likely to occur within 64 hours. Therefore, the transfer of ^{15}N verified in the greenhouse studies is attributed to direct N transfer mechanisms such as rhizodeposition by one plant and uptake by a neighbour plant and /or fungal hyphae bridges.

Water was applied directly to the pots' soil, and plants were not exposed to rain. Thus, N transfer by leaching of soluble N from plant leaves, as described by Whitney and Kanehiro (1967), was not involved in the transfer of ^{15}N.

Studies using a split-root technique indicated that N transfer from soybean to corn plants colonized by mycorrhiza (*Glomus fasciculatus*) was enhanced (van Kessel et al., 1985). Later field studies with the same crop species supported this findings (Hamel and Smith, 1989). Fungal hyphae bridges may have accounted for part of the ^{15}N transfer verified in the greenhouse experiments as no treatment to eradicate soil fungi inoculum was applied, and alfalfa and bromegrass plants did grown as intercrops for 181 days before ^{15}N treatments were imposed.

Greenhouse studies (Virtanen et al., 1937; Wilson and Wyss, 1937; Ruschel et al., 1979) indicate that nitrogenous compounds may be excreted by nodulated legumes and then utilized by an associated non-N_2 fixing plant. Active exudation or passive loss of nitrogenous compounds by associated plants was definitively involved in the ^{15}N transfer verified in the greenhouse studies.

Overall, alfalfa acted as a ^{15}N-donor whereas bromegrass was mainly a ^{15}N-receptor. The predominance of ^{15}N transfer towards bromegrass are likely due to: 1) higher N content of alfalfa than bromegrass (3.8 vs. 1.5 %); 2) larger root surface area of bromegrass than alfalfa; and 3) limited legume competition for soil-N.

N transfer by combination of direct and indirect mechanisms

The forage and N yield observed in July 12, 1991 are the cumulative result of the interrelationships between bromegrass and alfalfa neighbouring plants during 15 months. A combination of direct and indirect N transfer mechanisms were involved.

Direct N transfer mechanisms, such as leaching of soluble N from leaves by rainfall and irrigation, fungal hyphae bridges, and rhizodeposition of nitrogenous compounds are involved in the observed yields.

Defoliation of white clover has been shown to accelerate the breakdown of root and nodule tissue and the regrowth of new tissues. It was suggested that in aged (as opposed to newly established pastures) the decay of these tissues along with other root tissues would constitute a major source of transferable N (Herriot and Wells, 1960). In this study the sloughing and decay of roots and nodules induced by hay harvests and winter freezing is likely involved in supplying transferable N.

Greenhouse studies indicated that shedding of mature leaves from desmodium (*Desmodium intortum* (Mill.) Urb.) and centro (*Centrosema pubescens* Benth.) accounted for significant amounts of N transfer to associated pangola grass (*Digitaria decumbens*) (Whitney and Kanehiro, 1967). From early spring to June 20, 1991 approximately 14.4 and 6.5 kg of N ha^{-1} were returned to the soil through leaf fall respectively by intercropped alfalfa and intercropped bromegrass (non published data). Thus, leaf fall likely accounts for part of the increased yield of bromegrass plants located close to alfalfa plants.

In general, the N benefits for the bromegrass plants in the field occurred due to: 1) different effect of the legume and non-legume plants on the soil biology and chemistry; 2) the influence of plant competition on root distribution and soil N uptake; 3) limited legume competition for soil-N; and 4) transfer of symbiotically fixed N to the grass.

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FERTILIZER APPLICATION AND DEEP LEACHING OF NITRATE UNDER LONG TERM CROP ROTATION

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ABSTRACT

It is commonly believed that the use of nitrogen fertilizers in agriculture will lead eventually to the loss of nitrate via leaching. The nitrate leached below the root zone has the potential to contaminate underground water. The results obtained from various long term crop rotation studies in Saskatchewan suggest that this common belief may not hold in general. This is especially true where nitrogen fertilizers were applied based on soil test recommendation and the land was continuously cropped. Under long term crop rotation studies in the Black Soil Zone at Melfort, the application of nitrogen fertilizer in recent years were based on the general recommendation for wheat. The deep core sample revealed that more nitrate was present in the soil profile under fertilized continuous wheat compared to the unfertilized plots. However, in the Black Soil at Indian Head, where fertilizer application was based on soil test values, similar amounts of nitrate were found below the root zone of fertilized and unfertilized plots after 34 years of continuous wheat. This was in spite of applying 1584 kg of N ha^{-1} to the fertilized plot over 34 years. A result similar to that at Indian Head was obtained from the crop rotation experiment in the Brown Soil Zone at Swift Current. In the Brown Soil Zone, the inclusion of a fallow phase in the rotation, increased the amount of nitrate found below the root zone although this system had received less fertilizer over the years than the continuously cropped plots. The fallow phase appeared to provide a window for the leakage of nitrate accumulated within the root zone. This was attributed to a better moisture (antecedent moisture) regime and higher amount of mineralized nitrate during the fallow phase. On the other hand, frequent summerfallow can deplete the soil of its N supplying power and this may eventually result in less nitrate leached as was found for the 2-yr rotation at Indian Head after 34 yr.

INTRODUCTION

The deep leaching of nitrate from agricultural land is of concern for two main reasons: (i) the nitrate once leached beyond the root zone cannot be recovered, except by deep rooted grasses and legumes, thus representing a loss from the system; (ii) the leached nitrate has the potential to contaminate underground water, especially in areas where the water table is close to the soil surface.

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Nitrate nitrogen is very mobile in the soil and when present in large quantity can readily move with water down the soil profile unless it is taken up by plants, by microorganisms, or it is lost by gaseous means. In any given system, the quantity of nitrate that is leached will depend on the amount and distribution of rainfall, the quantity of nitrate in the soil and the soil physical parameters of texture and structure.

Nitrate production in the soil is a natural process that occurs irrespective of human interference. Under grassland however, the amount of nitrate lost is minimal (Campbell et al 1976) as a result of several factors, one of which is the deep rooted nature of grasses which permits the recovery of leached nitrate before it is carried deeper into the soil profile. Also, under grassland, there is a better synchrony between nitrate mineralization and uptake. Breaking and cultivating grassland soils disturbs the natural "check and balance" and inevitably results in nitrate leaching (Campbell et al 1976).

It is generally believed that the loss of nitrate through leaching can be influenced by fertilizer management and other management practices. Nitrogen fertilizers are applied to agricultural crops in order to augment the natural supply and meet the plant requirements for this essential nutrient. To determine the appropriate level of fertilizer input, producers conduct soil testing. Ideally the quantity that is applied should be such that it meets the plant demand for that particular nutrient. In practice however, this may not be the case. Testing may be inaccurate, not thorough enough, and in many cases it is not undertaken at all. A middle of the road approach is the use of the "generally recommended" levels for a specific crop in a particular soil zone. This practice is adopted by over 70% of farmers in Saskatchewan (Personal communication Saskatchewan Soil Testing Lab). If nitrogen is applied in excess of plant demand, large quantities will remain in the root zone which can be leached when rainfall is above average.

It is commonly believed that the application of nitrogen fertilizer will increase the amount of nitrate that is leached from agricultural soils. Several long-term crop rotation experiments being conducted in the major soil zones in Saskatchewan provided the opportunity to assess the influence of fertilizer application on nitrate leaching in these soils.

MATERIALS AND METHOD

The three ongoing long-term (>20 yr) crop rotation studies reported in this paper are conducted in the Brown Soil Zone (Swift Current), the thin Black Soil Zone (Indian Head) and thick Black Soil Zone (Melfort) of Saskatchewan.

The Swift Current crop rotation was initiated in 1967 and was established on 81, 0.04 ha plots located on a Swinton Loam (Mitchell 1944) an Orthic Brown Chernozem in a three replicate experiment. The details of the design and methods of this experiment are available in the literature (Campbell et al. 1983 a,b).

The crop rotation experiment at Indian Head was established in 1958 on Indian Head Heavy Clay (Mitchell,1944), a thin Black Chernozem. Further information on the experimental design and treatment are provided by Zentner (1987) and Campbell et al. (1991).

The crop rotation at Melfort was set out in a randomized block design with four replicates. The experiment was initiated in 1957 on a Melfort silty clay loam, an orthic Black Chernozem. This study has been previously described by Zentner et al. (1990) and Campbell et al. (1991). Tables 1-3 show the crop rotations originally established at these sites.

At various times during the growing season of 1990 deep cores were sampled on some of these rotations. The samples were taken up to 300 cm in 1990 but were extended to a depth of 450 cm in 1991 at the Indian Head site to provide information on the deep leaching of nitrate. Soil samples from each 30 cm segment were taken and analyzed for nitrate, moisture and bulk density.

Table 1. Crop rotations treatment at Swift Current

Rot. no.	Rotations	Comments
1	(Fallow)†-wheat-(wheat)	P applied as required but no N applied
2	Fallow-wheat-(wheat)	N and P applied as required
3	Fallow-flax-(wheat)	N and P applied as required
4	Fallow-(fall rye)-wheat	N and P applied as required
5	Fallow-wheat-wheat	N applied as required, no P applied
6	(Oat hay)-(wheat)-wheat	N and P applied as required; oats cut for hay at soft dough stage
7	Flax-wheat-wheat	N and P applied as required
8	(Continuous wheat)	N and P applied as required
9	Continuous wheat‡	[Fallow if less than 60 cm moist soil at seeding time.] N and P applied as required
10	Continuous wheat‡	[Fallow if grassy weeds become a problem] N and P applied as required
11	Fallow-(wheat)	N and P applied as required
12	(Continuous wheat)	P applied as required, no N applied

† Special plots indicated by (); these treatments were sampled for nutrients, soil moisture and plant growth at eight regular intervals (see text).

‡ Rotations 9 and 10 were cropped continuously because the criteria necessary for fallowing did not occur during the 12-yr study period.

Table 2. Crop rotations and fertilizer treatments at Indian Head

Rot.	Rotation sequence†	Fertilizer application‡^{y}	Replicates	Plots
1	F-W	No	6	12
2	F-W	Yes	6	12
3	F-W-W	No	6	18
4	F-W-W	Yes	6	18
5	F-W-W (straw removed)	Yes	6	18
6	GM-W-W¶	No	5	15
7	F-W-W-H-H-H¶	No	6	36
8	Cont W	No	6	6
9	Cont W	Yes	6	6
Total:				181

‡ Yes, No refer to fertilized with N and P and not fertilized, respectively.

¶ Hay = bromegrass-alfalfa hay; green manure = sweet clover.

^{y} Throughout the study, the average annual rate of P applied to wheat grown on fallow and stubble was 10 kg ha^{-1} and for wheat grown on fallow the average annual N was 6 kg ha^{-1}. For stubble-seeded wheat the average annual rate of N was 24 kg ha^{-1} for the period up to 1977 and 82 kg ha^{-1} thereafter.

Table 3. Rotations and fertilizer treatments at Melfort

Rot.	Rotation sequence†	Fertilizer application‡	Plots
1	F-W	Yes	8
2	F-W-W	No	12
3	F-W-W	Yes	12
4	GM-W-W	Yes	12
5	F-W-W-H-H-W	No	24
6	F-W-W-H-H-W	Yes	24
7	Cont W	No	4
8	Cont W	Yes	4
		Total	100

† Green manure refers to sweetclover and hay refers to bromegrass-alfalfa.

‡ The average annual rates of P applied to wheat grown on fallow and stubble were 15.5 kg ha^{-1} and for hay it was 6.5 kg ha^{-1}. The average rates of N were 14, 52, 34, and 79 kg ha^{-1} for wheat grown on fallow or GM, on wheat stubble, on hay, and for hay crops, respectively. Rates were higher in the second half of the study period.

RESULTS AND DISCUSSION

For the purpose of our discussion, the soil profile will be divided into two segments, The first segment (0-120 cm) is regarded as the rooting depth of spring wheat and the second segment is the portion of the soil profile below 120 cm. The amount of nitrate nitrogen in the top 120 cm segment of the soil is highly variable and is a reflection of the short term changes as a result of fertilizer addition, long period of fallow, mineralization and plant uptake. The measurement of the amount of nitrate leached was indirect and based on the quantity of nitrate present in the portion of the soil below the rooting depth. This soil zone reflected medium to long term treatment effect on nitrate leaching.

Fertilizer effect on nitrate levels with depth at Melfort

The result obtained at Melfort when samples were taken to a depth of 300 cm at harvest in 1990 is shown in Figure 1. Although soil sampling was carried out at harvest, a large quantity of residual nitrate remained within the rooting zone under the fertilized plot. It thus appeared that the quantity of nitrate available in the rooting zone of fertilized continuous wheat was far in excess of the plant requirement. This was probably due to the method of fertilizer application on this plot. In recent years fertilizers have been applied to the Melfort plots based <u>on the rates generally recommended</u> for wheat in the Black Soil Zone without considering the amount of residual mineral N in the root zone. With such a large quantity of nitrate in the root zone the chances of nitrate leaching into the subsoil is high during wet years.

This seemed to be the case when we take a look at the layers below the rooting depth. The quantity of nitrate present in the subsoil under fertilized continuous wheat was significantly higher than unfertilized wheat. The distribution of nitrate-N within the 120-300 cm soil zone was a reflection of medium to long term effect and not due to effect of the current season alone. This is because rainfall penetrates into different depths of soil carrying along nitrate and the effect is cumulative.

The result obtained at Melfort provides evidence that the use of general recommendations as a guide in fertilizer application may result in excessive fertilization. There is an economic cost in terms of the waste of fertilizer and also a potential environmental cost due to the leakage of nitrate-N into the soil profile.

Fertilizer effect on nitrate levels with depth at Indian Head

The results obtained at Indian Head when the different rotations were sampled to 450 cm in May-June 1991 is shown in Figure 2. The quantity of nitrate in the top 120 cm of the soil is a reflection of the recently added fertilizer nitrogen as the soil was sampled between May and mid June. As expected, more nitrogen was found within the rooting depth of the system that received nitrogen compared to the system that has never been fertilized in 34 years. The quantity of nitrogen in the root zone at Indian Head in late spring was smaller than that measured after harvest in the comparable treated rotation at Melfort in 1990.

In contrast to the results obtained at Melfort, a similar amount of nitrate was found in the subsoil of fertilized and unfertilized continuous wheat plots at Indian Head. This result was in spite of the fertilized plot having received 1584 kg N ha^{-1} during the 34 year compared to no nitrogen addition for the unfertilized plot. At Indian Head, nutrient application was <u>based on the soil test recommended rates</u> of fertilizers, this may partly be responsible for the similar levels of subsoil nitrate found in the fertilized and unfertilized continuous wheat at Indian Head. Also, it is hypothesized that the application of adequate amount of fertilizer may not exacerbate the deep leaching of nitrate. Fertilization should result in a vigorous plant which utilizes soil nitrate more efficiently.

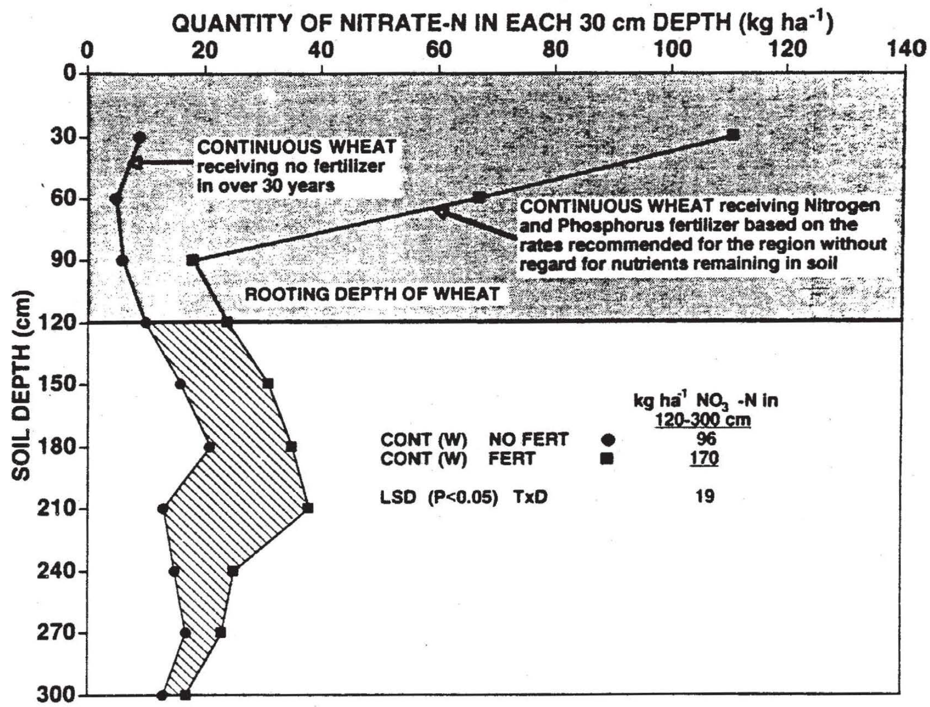

Figure 1. Nitrate-N distribution as influenced by fertilization of continuous wheat at Melfort.

The effect of fertilizer application on the deep leaching of nitrate appeared to be modified by crop rotation treatment e.g. the presence or absence of a fallow phase in the rotation (Figs 2 & 3). As shown in Figure 2, the fertilized 3-year F-W-W rotation, that received 647 kg ha^{-1} during the experimental period, as compared to 1584 kg N ha^{-1} for the continuous wheat had a significantly higher quantity of nitrate in the subsoil than the continuous wheat. The presence of a fallow phase in the 3-year F-W-W rotation may be responsible for this result. Leaving the land fallow usually results in net mineralization and build-up of nitrate. As well, there is a higher moisture regime under fallow and no crop uptake. When a fallow year coincides with a wet year, conditions are optimum for nitrate leaching. For a long-term rotation experiment such as this, the possibility of such coincidence is likely especially in the humid Black soil zone.

The effect of fertilizer addition on the nitrate lost from a 2-year F-W rotation is similar to that discussed for continuous wheat. There was no significant difference between the quantity of nitrate found in the 120-300 cm zone of fertilized and unfertilized F-W plots. This was not the case for the 3-year F-W-W rotation, however (Fig.3). The quantity of nitrate found in the subsoil of a fertilized F-W-W plot was significantly higher than that of the unfertilized plot. This result was somewhat surprising. Also surprising, was the smaller quantity of nitrate that was present in the subsoil of a 2-year rotation (F-W) at Indian Head compared to either at the 3-year F-W-W or the continuous wheat rotation. Since the F-W rotation had more incidence of fallow, it was expected that more nitrate would be lost in this system than either the continuous wheat or the F-W-W. A possible explanation is that the 2-year F-W rotation had lost considerable nitrate over the years to a greater depth than was sampled here. Campbell et al. (1990) reported that the N supplying power of the F-W rotation was the lowest of all rotation treatments. The soil under this rotation may be degraded to the level of producing little or no nitrogen for leaching in recent years and hence a cleaner subsoil than rotations with a higher N supplying power. Support for this assertion is the very low NO_3-N content found in the root zone of F-W in June 1991, 10 months after the commencement of fallow (Figure 3).

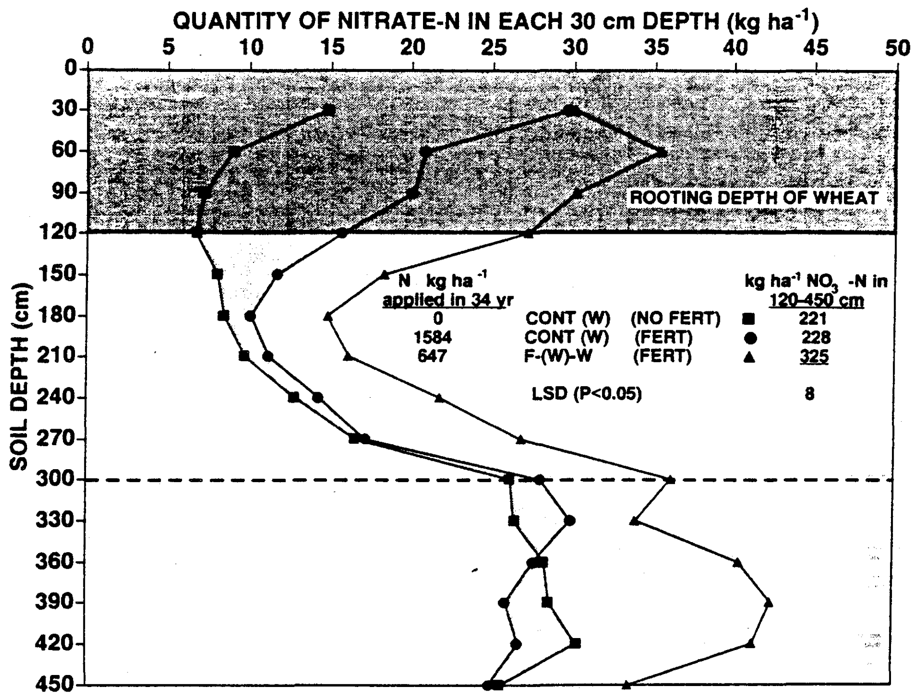

Figure 2. Nitrate-N distribution as influenced by fertilization of continuous wheat at Indian Head (Sampled May-June 1991).

Fertilizer effect on nitrate levels with depth at Swift Current

In the drier region at Swift Current, when continuous wheat was fertilized based on soil test recommendations, there was more NO_3 located in the subsoil of the poorly fertilized system than under the well fertilized rotation (Figure 4). The same effect of fertilizer was observed at Swift Current for the F-W-W system with well fertilized versus poorly fertilized rotations (Figure 5). These results can be partly explained in terms of N uptake and export from the system. Systems that are properly fertilized result in greater N uptake and a higher N export via grain. As a result, there is less NO_3-N available in the soil which can then be leached in wet fallow years.

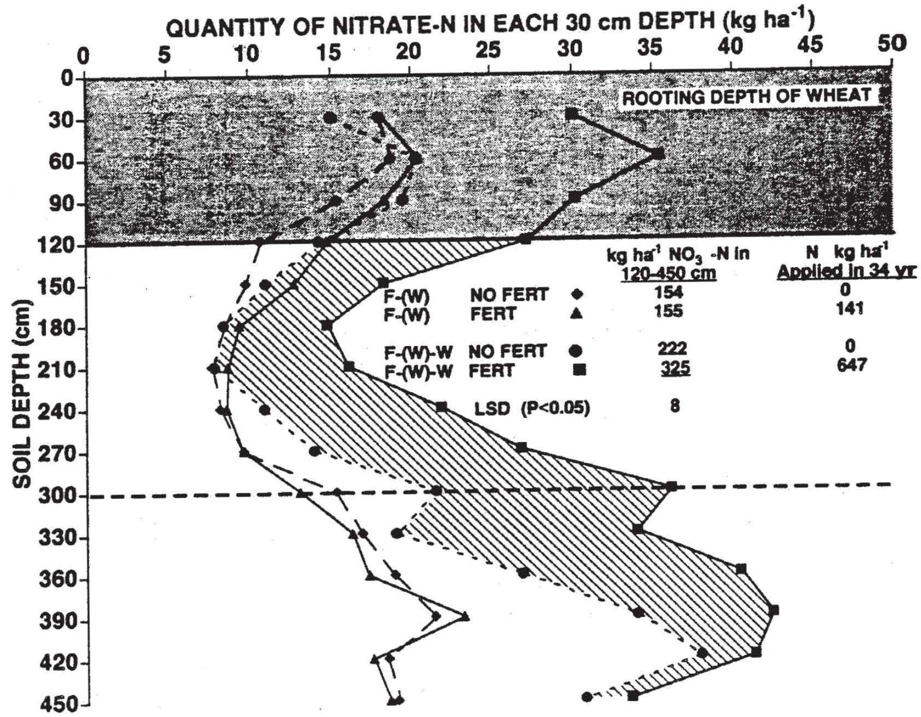

Figure 3. Nitrate-N distribution as influenced by fertilization in 2-yr and 3-yr rotations at Indian Head (Sampled May-June 1991).

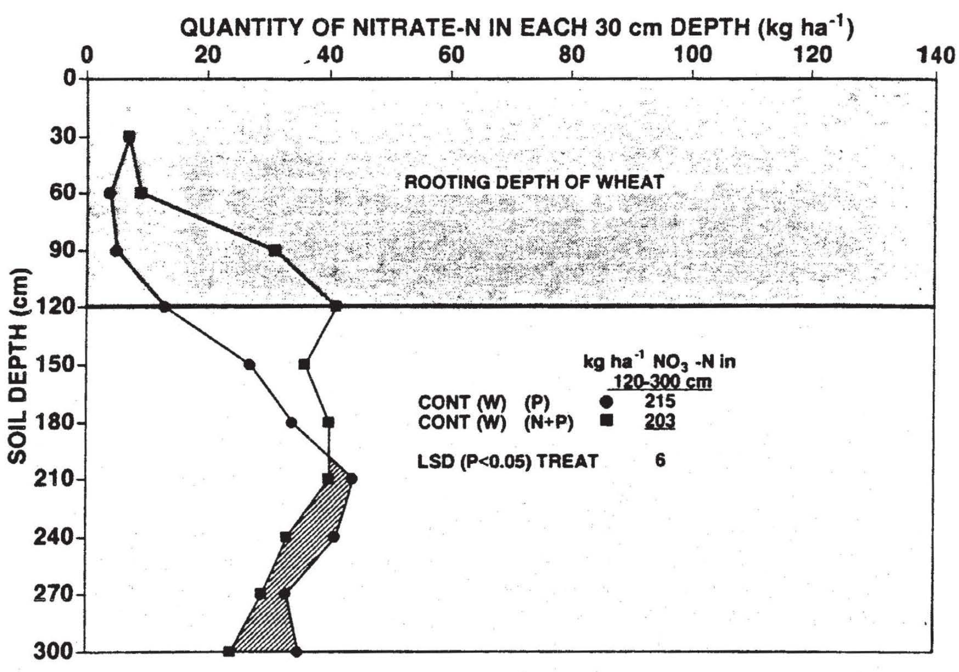

Figure 4. Nitrate-N distribution as influenced by fertilization of continuous wheat at Swift Current (Sampled July 31, 1990).

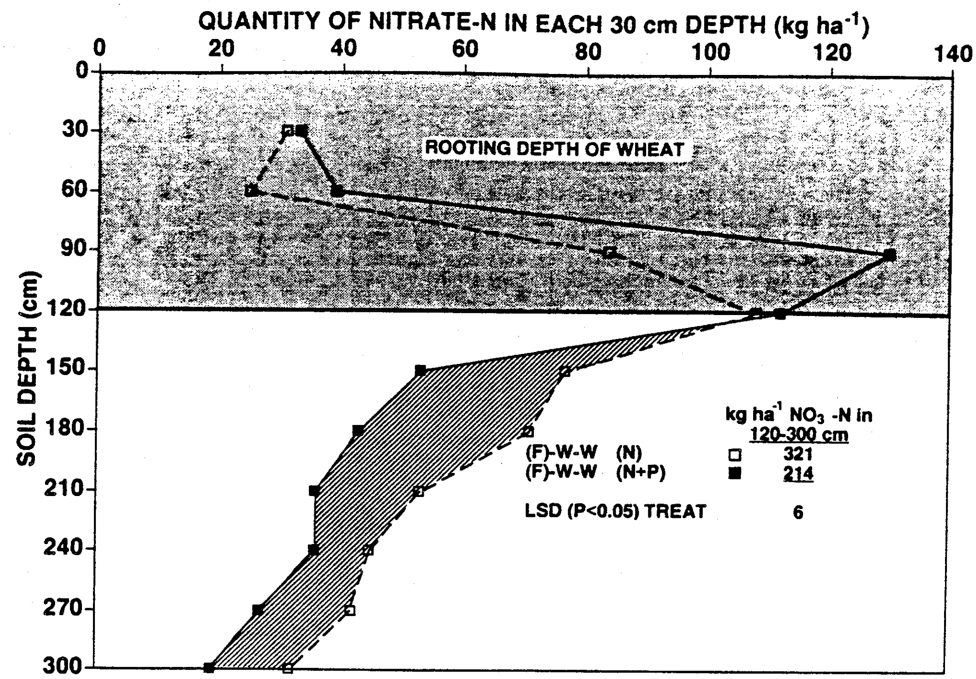

Figure 5. Nitrate-N distribution as influenced by fertilization of a fallow-wheat-wheat rotation at Swift Current (Sampled July 31, 1990).

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